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Investigating the Response of *Dracaena marginata* and Physical Characteristics of Growth Medium to Different Levels of Zeolite in Replacement for Peat

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Abstract

Due to the economic and environmental limitations in the use of peat moss as a growth medium of ornamental plants, researchers seek an appropriate alternative in flower and plants industry. Zeolite is a good candidate to replace peat moss because of its high capacity of water holding and cation exchange. This research addresses the feasibility of substituting peat moss by zeolite as a growth medium of *Dracaena marginata*. The control medium was a 2:1 ratio of peat:perlite and six levels of zeolite (0, 10, 20, 30, 40 and 50% v/v) in the replacement of peat were used in a completely randomized design. Some chemical and physical characteristics of growth media were measured including EC, pH, total nitrogen, organic carbon, C/N ratio, available phosphorus, potassium, calcium, magnesium, bulk density, porosity, and field capacity. The plant growth parameters were also measured including height, stem diameter, leaf number, and fresh weight of leaves, roots and stem. The highest stem height was obtained from 10% v/v treatment of zeolite. However, stem height did not show a significant difference with control in 40 and 50% v/v zeolite. Fresh weight of leaves was greater than the control in all zeolite treatments, and in other growth indices, 10% v/v treatment entailed a better response of plants. The bulk density was increased and the porosity was decreased with the increase in zeolite. Porosity, EC, aeration porosity, and field capacity had the highest effect on the growth indices in 10-20% v/v zeolite.

Keywords: Nutrition, Ornamental plant, Soilless media, Zeolite.

INTRODUCTION

Based on the international data, ornamental leaf plants that were worth USD 130 million in the US in 1949 were worth USD 574 million in 2000, indicating the progress and development of ornamental leaf plant during 50 years (Maboeta and Resenburg, 2003). In recent years, some problems in soil cultivation (soil salinity and inappropriate properties) and water resources limitations have led to the development of soilless cultivation (Borji *et al*., 2010).

Most ornamental leaf plants are cultivated in soilless media among which peat is a basic medium (Atieyh *et al*., 2000), but there is a limitation in the use of peat due to ecological damages to the environment. Therefore, growers are interested in the use of high-quality, yet inexpensive, substrates instead of peat (Krumfolz *et al*., 2000).

One of the principal factors in growing ornamental plants, particularly pot plants, is the use of an appropriate growth medium. A major limitation of pot plant export is the lack of appropriate growth medium in Iran (Padasht and Gholami, 2009). Researchers have investigated the possibility of using plant residuals, *Cocos nucifera*, and minerals such as zeolite instead of peat (Manolov *et al*., 2005). Some studies have shown that organic wastes such as municipal wastes, sewage sludge, livestock manure, paper, and other organic waste can be used after composting as a growth substrate for ornamental plants (Gayasinghe *et al*., 2010).

Natural zeolites are used as a new growth bed in the cultivation of ornamental plants (Manolov *et al*., 2005). The commercial production and application of zeolite date back to 1950 (Polat *et al*., 2004). It has been reported that zeolite has increased the yield of tomato, pepper, carrot, and wheat (Samartzidis *et al*., 2005). Natural zeolite with high CEC and macro-micro nutrients can be used in providing industrial beds (Manolov *et al*., 2005). The growth of plants in beds having zeolite with or without peat, vermiculite, etc. is called zeoponic (Mumpton, 1999). Nowadays, zeolite is applied in the reclamation of physical and chemical properties of soil (Abdi *et al*., 2006).

The aim of this study was to investigate the feasibility of replacing peat with zeolite in the growth medium of ornamental plants given the inexpensiveness and availability of zeolite resources in Iran.

MATERIALS AND METHODS

This experiment was carried out in Ornamental Plants and Flowers Research Center, Lahijan, Iran to evaluate the impact of zeolite as a replacement of peat in the growth medium of *Dracaena marginata*. The used zeolite was clinoptilolite with a diameter 3-8 mm. Some chemical characteristics (total nitrogen, phosphorus, potassium, and calcium, EC and pH in 1:5 extract zeolite to water) were measured (Table 1).

Table 1. Some chemical characteristics of zeolite and peat moss used in the experiment.

Material	Nitrogen (%)	Available phosphorus (%)	Available potassium (%)	Available calcium (%)	EC ($mScm^{-1}$) (1:5)	pH (1:10)
Zeolite	0.003	0.001	0.64	0.84	2.35	9.2
Peat	0.03	0.03	0.03	0.51	0.32	5.6

Dracaena marginata that was selected as the test plant is a perennial with evergreen shiny and smooth leaves often with a cluster makeup at the end up. This species has lower chlorophyll content than typical green species (Edwards, 1999). A completely randomized block design was used with six treatments including:

1. Control: Basic medium of dracaena ornamental plant was a 2:1 v/v peat:perlite;
2. 10% zeolite: Peat was replaced by 10 v/v of zeolite in the medium;

3. 20% zeolite: Peat was replaced by 10 v/v of zeolite in the medium;
4. 30% zeolite: Peat was replaced by 10 v/v of zeolite in the medium;
5. 40% zeolite: Peat was replaced by 10 v/v of zeolite in the medium; and
6. 50% zeolite: Peat was replaced by 10 v/v of zeolite in the medium.

Therefore, six treatments, each in three replications, were used in the study. The peat was procured in ready form from SAB Company, Germany. After preparing beds, the rooted cuttings of dracaena were transferred to the pots (4 L). First, after preparing media, the rooted cuttings of dracaena removed from transplant pots and the roots were washed completely. Then, one plant was cultivated in each pot with the new bed and it was placed in a greenhouse. Plant height, leaf number, and leaf, stem, and root dry and fresh weight were measured at the end of the experiment. During the growth, the bed was fertilized with Omex (Table 2).

Table 2. The components of the applied fertilizer (OMEX).

$N(NH_4, NO_3)$ (%)	P_2O_5 (%)	K_2O (%)	S (%)	Mg (%)	Cu (ppm)	Zn (ppm)	Fe (ppm)	Mn (ppm)	Mo (ppm)
18	18	18	0.4	2	16	14	70	42	14

Total Kjeldahl nitrogen (TKN) and total organic carbon (TOC) of the media were measured by using the micro-Kjeldahl method (Singh and Pradhan, 1981) and Walkey and Blacks (1934)'s rapid titration method, respectively. The pH and EC of beds were determined on a water extract from compost using a compost:water ratio of 1:5 by weight. Phosphorus and potassium were determined by the spectrophotometric and flame photometric methods, respectively. Some physical properties of the beds including bulk density, total aeration, and field capacity were measured (Gabriels *et al*., 1993).

The leaves were harvested after four months and the dry matter yield was determined after they were dried at 70°C for 48 h. The sub-samples of the dried leaves were ground, dry-ashed in a furnace at 550°C, and extracted with 2M HCl. The concentrations of Ca, Mg, Fe, Mn, and Zn were measured in the extracts by atomic absorption spectrophotometry, K by flame photometry, and P by spectrophotometry.

The experiment was based on a completely randomized design in three replications and MSTATC software was used for variance analysis of data by the Least Significant Difference (LSD) test.

RESULTS AND DISCUSSION

Physical and chemical characteristics of cultivation media

Table 3 shows the chemical characteristics of the used beds. The amount of nitrogen and phosphorus was decreased in beds proportional to zeolite application, but K concentration showed a sharp increase versus control so that the highest K (218.6 mg/kg) was observed in 20% zeolite. Chemical properties of the growth media should be considered because they have a high impact on plant quality. Chemical properties affect nutrient dissolution and their exchange directly (Robert and Browder, 2005). Due to the existence of N and P in organic matter (peat) compound, the replacement of peat by zeolite as a mineral compound decreased N and P in the media. These results are in agreement with Abdi *et al*. (2006)'s study on zeolite beds of strawberry cultivation. Due to its high K content, Zeolite increases the K content of substrates (Williams and Nelson, 1997). Challinor *et al*. (1995) reported that clinoptilolite absorbed K and decreases K leaching. The greatest C/N ratio (55.7) was related to 40% zeolite and the lowest (20) was obtained from 20% zeolite.

The C/N ratio in growth media was lower than the permitted level (C/N=30) for the growth of ornamental plants.

Table 3. The chemical properties of the media used in the experiment.

Medium	N (%)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	Organic Carbon(%)	C/Nratio	pH (1:5)	EC (ds m^{-1}) (1:5)
Control	0.8	26.3	50.0	7.6	81.3	276.0	37.6	47.0	5.8	1.41
10% Z*	0.73	13.5	129.9	44.0	76.8	306.4	20.3	27.8	6.7	1.48
20% Z	0.63	10.4	218.6	22.8	34.8	284.5	12.6	20.0	6.4	1.64
30% Z	0.50	7.2	163.2	26.0	37.5	284.5	10.7	21.4	7.1	1.87
40% Z	0.35	7.3	180.0	28.0	52.3	324.4	19.5	55.7	7.3	2.16
50% Z	0.50	3.4	168.2	24.8	43.2	370.0	11.7	23.4	7.5	2.42

*Zeolite

Three factors of growth media including pH, EC, and CEC are important (Robert and Browder, 2005). Table 3 shows a decreasing trend in pH proportional to the used zeolite so that the highest and the lowest pH was related to 50% zeolite and control, respectively. The same trend is observed in the EC of media. The application of zeolite increases the pH of media (Kolar *et al*., 2010). This result is consistent with Mahboub Khomami (2011)'s study on the replacement of peat by zeolite in the substrate of *Ficus benjamina*.

Chen *et al*. (1988) report that the physical characteristics of substrates are the most important factor in plant growth. Proportional to the used zeolite in beds, the porosity was decreased so that the highest and lowest porosity (89 and 78%) was related to control and 50% zeolite, respectively (Table 4). Fonteno *et al.* (1981) report that porosity should be more than 85% in an ideal growth medium. In this study, only control treatment had an ideal porosity. Bulk density was increased in the media proportional to the used zeolite, resulting in the loss of porosity. Bulk density increases the number of pores and consequently the porosity (Robert and Browder, 2005).

Table 4. The physical properties of the media used in the experiment.

Medium	Bulk density (g/cm^3)	Porosity (%)	Aeration porosity (%)	Field capacity (%)
Control	0.28	89	48.4	40.62
10% Z*	0.43	84	43.3	40.65
20% Z	0.50	81	41.7	41.40
30% Z	0.54	80	34.4	45.60
40% Z	0.56	79	40.4	46.08
50% Z	0.60	78	30.9	47.10

Treatments effect on the growth of plant

Table 5 shows the results of ANOVA for the effects of treatments on plant growth indices. The effect of treatments on all measured traits of growth indices was significant at $P < 0.05$ or $P < 0.01$.

Table 5. The results of ANOVA for the effects of the treatments on plant growth indices.

SoV	df	MS				
		Height	**Stem diameter**	**Leaf number**	**Leaf fresh weight**	**Leaf dry weight**
Treatment	5	18.1**	0.2**	35.3**	72.7*	2.2*
Error	10	2.7	0.02	0.65	15.65	0.33
CV (%)	-	24.2	11.1	12.4	10.2	13.1
		Stem fresh weight	**Stem dry weight**	**Root fresh weight**	**Root dry weight**	
Treatment	5	16.3**	0.39**	423.4**	3.3*	
Error	10	2.2	0.08	67.8	0.63	
CV (%)	-	35.3	16.1	65.5	38.3	

*and **: Significant at $P < 0.05$ and $P < 0.01$ respectively.

Height, stem diameter, and leaf number

Figs. 1-3 show the effect of treatments on plant height, leaf number, and stem diameter. Based on Fig. 1, the highest height was related to the plants exposed to 10% zeolite, and the other treatments did not indicate a significant difference with control. Zeolite increased stem diameter significantly at all rates. The highest stem diameter and leaf number were observed in 10% zeolite. The increase in stem diameter is in agreement with Song *et al.* (2004) that reported an increase in stem diameter, leaf area, and seedling dry weight of peppers in proportion to the used zeolite. Totally, the highest growth indices were obtained from 10-20% zeolite, which is consistent with the results of Gul *et al*. (2005) and Markovic *et al*. (2000). Due to its high CEC, zeolite makes a balance in nutrients and pH of the root environment, thereby enhancing leaf and stem growth. An increase in leaf number has been reported by Kolar *et al.* (2010) and Mohammadi Torkashvand *et al.* (2013).

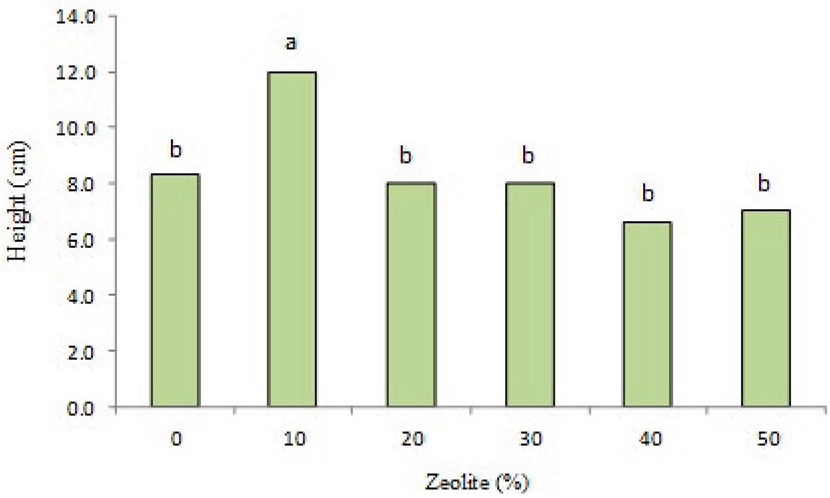

Fig. 1. The effect of zeolite on the plant height of *Dracaena.*

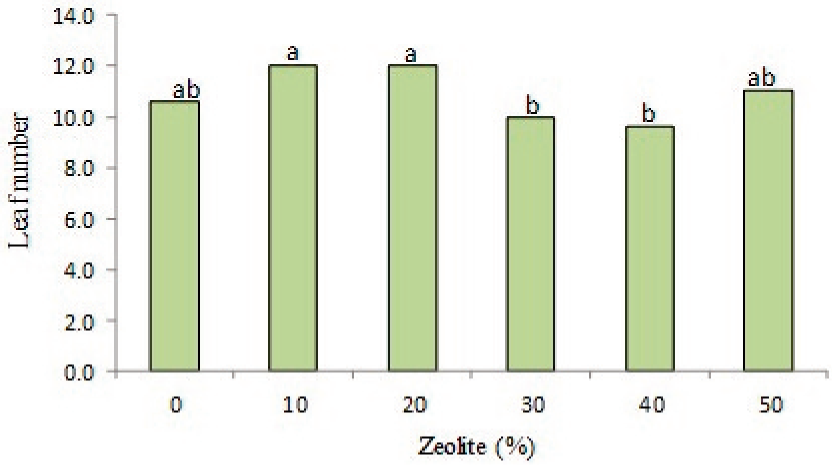

Fig. 2. The effect of zeolite on the leaf number of *Dracaena.*

Fig. 3. The effect of zeolite on the stem diameter of *Dracaena.*

Fresh and dry weight of leaves, stem and root

The greatest fresh weight of leaves was obtained from 20% zeolite treatment (Table 6). It seems that high CEC and water holding capacity of zeolite tend to prevent nutrient leaching; and nutrient availability has increased leaf fresh weight (Shaw and Anderws, 2001). Zeolite increases available water to root. Kolar *et al.* (2010) reported that *Geranium* grown in lower rates of zeolite had a higher stem dry weight than those grown in higher rates of zeolite. Gul *et al*. (2005) investigated different ratios of perlite to zeolite in the growth medium of lettuce and concluded that the increase in lettuce weight was in proportional to the used zeolite. Munir et al. (2004) stated that zeolite prevented nutrient leaching and groundwater pollution due to the trapping nutrients.

Leaf and stem fresh weight showed a descending trend and most growth indices had no significant difference. The loss of plant growth in higher rates of zeolite (particularly 40 and 50%) is partially related to the decrease in aeration. The highest water volume percentage was obtained from 50% zeolite that was in agreement with Kolar *et al*. (2010). As a result of the replacement of peat by zeolite, the bulk density of the media was increased, resulting in a decrease in porosity. Therefore, the growth was decreased in 40-50% zeolite treatments due to the physical characteristics of the media emanating from the loss of aeration. According to Atiyeh *et al*. (2001), a sharp

Table 6. The effect of zeolite treatments on stem, leaf, and root fresh and dry weight.

Zeolite (%)	Leaf fresh weight	Leaf dry weight	Stem fresh weight	Stem dry weight	Root fresh weight	Root dry weight
0	12.51 e	1.12 b	8.04 c	1.47 d	6.71 b	1.10 c
10	13.67 de	1.23 a	8.61 c	1.51 bc	6.85 b	1.32 ab
20	19.53 a	1.24 a	11.43 a	1.72 a	7.32 ab	1.40 a
30	17.71 ab	1.21 a	10.43 ab	1.61 b	8.62 a	1.42 a
40	16.66 bc	1.19 a	9.41 bc	1.49 cd	7.43 ab	1.24 bc
50	15.03 cd	1.12 b	9.22 bc	1.55 bc	6.60 b	1.17 bc

* In each column, means with similar letter (s) are not significantly different ($P < 0.05$) using the LSD test.

increase or decrease in bulk density is not appropriate because of its effects on aeration, porosity, and water holding capacity. In addition, the loss of growth in zeolite rates of higher than 20% may be attributed to the higher EC, pH and C/N ratio. In conclusion, the best treatment was the use of 10-20% zeolite in the media to achieve a better growth of dracaena.

CONCLUSION

Based on the results, the use of zeolite promoted physico-chemical characteristics of the media, but the higher rates of zeolite (40-50%) were inappropriate. The growth was increased in all zeolite treatments versus the control, but the treatment of 10% zeolite induced a better response in plants.

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